X-847

Health Physics —
Radiation Exposure
Accidents — Env

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

December 2, 1959

This document has been approved for release to the public by:

David R Hamrin 11/17/95
Technical Information Officer Date
ORNL Site

TO: A. M. Weinberg

FROM: K. Z. Morgan

SUBJECT: Preliminary Report of Action Taken by the Health Physics Division Following the Explosion at ORNL on November 20, 1959

A. Summary and Conclusion

I consider this potentially the most serious radiation accident in the history of ORNL. It may be many years before we are aware of the more important consequences of this accident.

B. Introduction

On Friday night about 10:50 p.m. the Health Physics supervisor, J. A. Worth, was walking between Buildings 3001 and 3042 when he heard what appeared to be an explosion. He got into his car and hurried up Hillside Avenue in the direction of the cafeteria. He had gone only a few hundred feet and reached the point in front of cell 6 in Building 3019 when he observed that the cement blocks which had been stacked in front of the door of the cell, as well as the door itself, had been blown toward the street. He had with him a gamma survey instrument and with this he made a hurried survey finding a reading of about 15 mrem/hr in the middle of the street at a distance of about 30 feet in front of the opening of cell 6. He took several smear samples by rubbing filter paper on the road and hurried to the guard gate at the northwest side of Building 3019.

At first it was thought that there was no serious radiation hazard so that when Mr. Worth informed me over the phone shortly before midnight of the chemical explosion, no mention was made of the α-activity. The primary concern at that time was with the low β-γ dose rate readings in and about Building 3019 and with restricting the spread of the contaminated dust from cell 6, so I considered that the explosion had resulted in no serious damage and that all necessary precautions had been taken. No one had gone into cell 6 (nor has anyone gone into cell 6 to date, December 2) to determine the exact source of the explosion, because it was evident that there was a major dust hazard and that the radiation level close to the door was reading several rem per hour.

Alpha survey readings are not made routinely outdoors, especially on a night when the relative humidity is close to 100 per cent, because of unreliability of such instruments under humid conditions, because alpha contamination of serious consequences has seldom, if ever, appeared outside

ChemRisk Document No. 2634

no - it is the objective of a sepes plant to separate α from β + γ normally

(4) the confines of our buildings, and because α-activity is ordinarily accompanied by β-γ activity. It was not until about an hour later when the Health Physics surveyor A. C. Butler made a routine check of his shoes and found them badly (5) contaminated with α-activity that anyone suspected this problem. In retrospect, it is hard to understand why the operators or supervisors of the operations in Building 3019 did not suggest to Mr. Worth or to the Laboratory shift supervisor that α contamination might have escaped from the vessels in cell 6 as a result of the explosion. In fact, during the early hours of Saturday it was not known whether the accident had resulted from a criticality assembly,* a zirconium explosion, or some other chemical explosion, and it was not until Dr. F. L. Culler arrived that many important questions could be answered. About 12:30 Butler obtained a good filter-paper sample from our constant air monitor in the "penthouse" above cell 6. This sample, together with similar samples collected by Health Physics surveyor R. E. Coleman and Chem Tech engineer D. E. Spangler, were counted for gross α-activity and later chemically analyzed for plutonium. It was some hours later that the plutonium analyses were completed, but the gross α count and the preliminary range analysis of the sample suggested strongly that there was a serious plutonium problem.

(7) Sometime before midnight J. A. Worth made a masterly decision by setting up a guard post and a Health Physics checking station on the road below the cafeteria at the corner of 3rd Street and Central Avenue so that thereafter all persons leaving the area of Building 3019 were carefully checked for α-, β-, and γ-activity, and no one was permitted to enter this area unless he had been provided with appropriate protective clothing. If this checking station had not been established and if Hillside Avenue had not been blocked off to all traffic, it is quite probable that a large amount of plutonium would have been tracked throughout the Laboratory, thus putting it out of operation for many weeks.

It is somewhat ironical that one of the fortunate features of this accident was the fact that it followed closely on the heels of the ruthenium fallout accident such that Health Physics had three men on duty rather than (8) the usual one person who covers this shift. These men notified by phone other members of the Health Physics Division, and they, together with others who (9) arrived on the scene shortly thereafter, began systematic surveys of personnel and the entire area. One important and noteworthy step taken by Worth after the barricades were placed on Hillside Avenue was checking the Health Physics read-out panel which gives an indication of the contamination collected by ten (10) perimeter constant-air-monitoring stations (i.e., at the rock quarry, Jones Area, Buildings 1000 and 3025, etc.). It is interesting to note that the constant air monitor on the north side of Solid State Building (3025) went (11) off scale at 11:09 a.m.

---

*The nearest boron ball containing fission foils and the container of gold foil and sulfur were about 20 feet from cell 6. These samples were counted the night of the accident, and no fission or induced activity could be detected. However, the 5-foot concrete wall of cell 6 would have provided considerable shielding of (12) any neutron source in cell 6. Likewise, NTA films worn by employees in Building 3019 were developed, and there was no indication of proton tracks. Chemical analysis of smear samples did not indicate the presence of the usual complement of short-lived fission products (e.g., Sr^{91}, Sr^{92}, Ce^{143}, Mo^{99}, I^{133}, Cs^{137}, Ba^{140}, La^{140}, etc.), but all this evidence was slow in providing decisive evidence that there had not been a criticality accident.

One of the fortunate circumstances of this accident was that the Laboratory shift supervisor, Mr. G. C. Cain, was a former Health Physics employee coming on duty at 12 midnight. His previous training in health physics stood him well in this incident; for example, as soon as he became aware of the situation he cut off the water from the laboratory into White Oak Creek; thus averting the possibility of seriously contaminating the Clinch River system with plutonium.

C. <u>Recommendations Made by K. Z. Morgan on Saturday Night, November 21, 1959</u>

Because of the delay in recognizing that there was an α hazard and informing me of the same I did not arrive at the Laboratory until sometime between 1:00 and 2:00 a.m. Shortly afterward most of the senior members of the Applied Health Physics section (J. C. Hart, A. D. Warden, H. H. Abee, R. L. Clark, E. D. Gupton, D. M. Arthur, F. E. Brown, H. V. Hoecker, O. D. Teague, and L. C. Johnson) were present and sometime later in the night altogether about 30 members of the Health Physics Division were on hand taking part in various operations including area surveys, air sampling, perimeter surveys, personnel monitoring, urine and fecal analysis, water monitoring, etc. Having discussed the preliminary survey data with Mr. J. C. Hart and reviewed the probable cause and consequences of the explosion with Dr. F. L. Culler, we recognized that we faced an extremely serious problem in preventing the spread of what could be as much as 1200 grams of plutonium. With this in mind I made recommendations as follows:

1. <u>Look after the public health by:</u>

   a. Reducing to a minimum the water flow to holding basins.

   b. Cutting off water into and from Building 3019.

   c. Pumping the water containing the plutonium into the earthen pits in the waste disposal area where we could expect to obtain a 100% removal of the plutonium. Normally we obtain only 80 to 90% removal of plutonium in our lime soda-ash process treatment plant so the earthen pits seemed to be the best bet in this case. Rough calculations by H. H. Abee indicated we had about 44 mc of Pu in the holding basin so we did not wish to release this water through the treatment plant.

   d. By-passing to White Oak Creek all uncontaminated liquid waste in order not to dilute the impounded waste containing the Pu.

   e. Having Abee and his surveyors make numerous area surveys in the neighborhood of the laboratory.

2. <u>Look after health of ORNL employees by:</u>

   a. Checking skin contamination of those engaged in the operation. Several employees required extensive skin decontamination.

   b. Checking clothing of employees and by requiring coveralls, shoe covers, caps, etc., of everyone going into highly contaminated area.

c. Getting as many urine and fecal samples as possible from exposed (or potentially exposed) employees. The Health Physics urine analysis laboratory was operated on a 24 hour basis.

d. Getting a large number of smear samples, air samples and fall-out samples. These were analyzed by photographic and counting techniques.

e. Warning everyone to stay out of the contaminated area if possible and adding a special word of caution to prevent any employees entering the contaminated area with open wounds or engaging in any operations where they might run a risk of receiving contaminated wounds.

f. Maintaining personnel monitoring and clothing checking stations at the northwest corner of Building 3019 and the southeast corner of Building 3042. No one is to enter or leave the contaminated area except via these stations.

g. Making spot checks of shoes of all persons entering the cafeteria. NOTE: This check was conducted for two days with results as shown in Table I.

h. Making checks of all shoes of persons leaving the Laboratory. NOTE: This check was conducted for five days with results as indicated in Table I.

i. Notifying all Laboratory Directors of the accident. I phoned Dr. A. Hollaender with reference to the accident. Our Health Physics surveyor, L. C. Johnson, placed paper in the hallways of the Y-12 Biology Building and persons from X-10 were checked for contamination when they entered the Biology Building. The doors of the X-10 Instrument Building were sealed shut, paper was placed on hallways and persons entered only after putting on clean cover shoes. Papers were placed in entrance ways of other buildings.

j. Checking cars and trucks leaving X-10. A number of these were found to be contaminated and required decontamination. when?

k. Checking cafeteria thoroughly several times before its use in the preparation and serving of food.

l. Keeping a complete log of all persons entering and leaving the Laboratory from 12 midnight Saturday to 6:00 a.m. Sunday.

3. Pin down and secure the sources of high level Pu contamination by:

a. Placing tar and gravel on Hillside Avenue from west end of Building 3019 to east end of the ORR (Building 3042).

b. Spraying a heavy coat of paint on sidewalks, grass, fence, cement blocks, pipe, truck, and other objects immediately outside of cell 6.

c. Putting new surface on roof of the Solid State Building (3025) and the Engineering Building (3022).

d. Painting north and west walls of Building 3022 and treating in some satisfactory way the north wall of Building 3025. NOTE: I believe this treatment of the north wall of Building 3025 is one of the few recommendations I made that was not carried out immediately. (A brick sealer was added on December 1, after a mop down.)

e. Removing the contaminated truck from the south side of Building 3001 to the burial ground area without spreading the contamination. NOTE: This truck was moved temporarily to the decontamination area in the Isotope Area and was later taken by a crane to the burial ground. Perhaps when more time is available it can be decontaminated but it would always present some potential risk.

f. Sometime later the roof of Building 3019 was found to be contaminated and a new surface was placed on this roof.

4. <u>General cleanup programs now in various stages of progress:</u>

a. Digging out in large sections the contaminated portion of the hard surface of Hillside Avenue and carrying it to the burial ground.

b. Carefully loading and carrying to the burial ground the cement blocks, pipe, fence, etc., south of cell 6. These are some of the objects that were sprayed on Saturday with white paint.

c. Continuing our restrictions against eating and continuing to limit access to specified doorways in Buildings 3022, 3025, 3042, 3008, 3005, 3004, 3003, 3002, 3013, and 3074. Only our quick action on the early morning of November 21 prevented serious contamination of these buildings. The entrance-ways, air conditioners, and ventilators facing toward cell 6 were sealed off, blotting paper was placed on the floors and persons entering these buildings were checked for contamination and required to change into clean cover shoes. When we checked the ORR Building (3042) about 3:00 a.m. we could find no evidence of α contamination. However, when I re-checked the building about 6:00 a.m. a <u>considerable</u> amount of α-activity had been tracked through the west doorways. It is fortunate that this was caught in the nick of time. I had the doorways blocked (with the exception to one entrance on the east side of the building) and the contamination cleaned up in the hallways so that we could continue the use of the building.

Some of the supervisors and other occupants of these buildings have complained about the restrictions we have imposed. My own feeling is that we and they are fortunate to be able to use these buildings and we cannot relax these restrictions unless and until we are assured the persons using these buildings are not thereby subjected to serious Pu exposures.

d. Continuing a careful check on all liquid and gaseous waste from ORNL.

e. Continuing our suspension of the Saturday tours of high school children and others into the Laboratory area.

5. Cleanup of the Graphite Reactor Building (3001)

On Saturday morning about 4:30 a.m., when I entered the Graphite Reactor Building and found the floors and steps badly contaminated, I checked the shoes, clothing, hands, and face of each person working in the building, and in every case the shoes were very badly contaminated with α-activity. Fortunately, I did not find any indication of contamination on the clothing or bodies of these employees. Because it was evident that contamination was being spread rapidly by tracking and it was quite likely that some of the contamination was air-borne, I attempted to contact A. M. Weinberg for permission to shut down the reactor as soon as possible. (I had been informed that J. A. Swartout was out of town so I did not attempt to 'phone him.) Since I was not successful in awaking Dr. Weinberg, I requested that the reactor be cut off immediately but without damage to the reactor and that all persons leave the building as soon thereafter as possible. At that time we made a quick check of the filters and other parts of the building and, where possible, the fans drawing air into the building were cut off. All persons in the building were given sample bottles and requested to furnish urine and fecal samples for analyses. Further entry into the building was prohibited except by those wearing protective clothing and an appropriate mask (this was not to include a half face mask but rather a full face mask, a pressure mask or a pressure suit).

a. Clean up the spots of gross α-activity as soon as possible. NOTE: This has already been accomplished.

b. Close all doors, windows, and vents, especially those openings leading from the pipe tunnel of Building 3019 into the canal room of Building 3001. In retrospect it is evident that much of the contamination entered Building 3001 through these openings, through an open door on the west side and through two open windows on the south side.

c. Grind off the contaminated floor surface and replace it with terrazzo, tile, or some suitable surface that is more easily decontaminatable. This is the dustiest of the proposed operations and should come early in the cleanup operations.

d. Go over all surfaces where possible with a vacuum, sucking the contamination into the reactor and thence to the reactor filters and stack. Care must be exercised in order not to suck boron, cadmium, or other large capture cross-section material into the reactor. This vacuum treatment can be expected to effectively remove a large amount of the loose contamination around instrument panels, wiring, piping, ledges, etc. NOTE: In all these cleanup operations care must be taken to turn off the electric power in areas where these operations might introduce a high risk of electrocution.

e. Initially I frowned on the idea of washing down the roof and walls of this building with water because I feared much of the contamination might be washed into cracks and crevices and into the insulation between the corrugated sections of the building; such contamination only to be sucked into the building at a later date after the insulation has dried out. It has now been indicated that water cleaning can be applied to certain parts of the building without the risk as stated above and if this proves to be true the wash down method may be used satisfactorily in some parts of this building.

f. All the above cleanup operations must be carried out only by persons wearing a full face mask, a pressure mask, or pressure suit.

g. Building is to have a complete coat of paint inside. This has the advantage not only of retaining the remaining plutonium but also of forming it into large insoluble particles that present little or no lower respiratory tract hazard should the paint flake off at some future date. It is obvious that this building must be repainted frequently in the future so long as it is in use.

h. The final details of the cleanup of the Graphite Reactor and its concrete shield have not been worked out; presumably most of this can be accomplished with appropriate use of the vacuum system. The various plugs and stringers should be moved in and out of the reactor a few times in order to dislodge Pu particles collected in the crevices.

i. No food may be taken into Building 3001 and no food may be eaten in Building 3001.

j. No tobacco may be smoked or chewed in Building 3001.

k. No person with open sores may enter Building 3001. Great care must be taken to avoid wounds with contaminated objects. NOTE: In case of contaminated wounds (this includes any break in skin) the injured person must be rushed to the Medical Dept. for emergency treatment.

l. Upon completing the cleanup of Building 3001 the stack filters should be changed with great care in order not to discharge plutonium (from the clean-up operation) up the stack.

6. Cleanup in the Pilot Plant, Building 3019

A great deal of effort has been expended to obtain photographs or TV shots inside cell 6. I have indicated that this is an important assignment but it must be done without the risk of overexposure — either externally or internally.

a. The plugs and all openings into cell 6 must be carefully sealed.

b. The analytical end of Building 3019 was not contaminated following the explosion because the air flowed from this section toward cell 6. We must make certain that these areas remain sealed off and that they do not become contaminated.

c. One of the finest features of the accident is that the filters in the air stream from Building 3019 held and operated effectively.

I have requested that these filters be changed only after taking every known step to prevent the blowing of plutonium up the stack.

d. All other areas in the building must be cleaned up after careful planning and by following each procedure step by step as outlined above for Building 3001. The contamination in this building is perhaps several orders of magnitude greater than that in Building 3001, so the clean-up job is much more difficult.

e. There has been some cross contamination (feedback) due to the use of a common change house for Buildings 3019 and 3001. Plans are being made now (December 2) to provide a separate change house for Building 3001.

f. Several cages of animals (mostly rats) are to be placed in the "hottest" areas of Building 3019 during the clean-up operations. Some of these animals will be sacrificed to determine the magnitude of the inhalation hazard while others will be retained and observed for any late effects of plutonium exposure.

7. Personnel Exposure

It is impossible at the present time to evaluate exposure of ORNL personnel. As indicated in Table II, a large number of urine samples indicate that a small amount of plutonium is being excreted by most of the persons engaged directly in operations in Buildings 3019 and 3001. We have received only a few fecal samples for analysis, but as indicated in Table III two of these are rather high. There is no need for fecal samples at this late date except from those who continue to be exposed to plutonium, because most of the elimination at present would be by way of the urine. Preliminary tests have indicated that the plutonium which escaped is quite insoluble in water. We would like very much to get a large sample and determine its solubility in body fluids. We would like to obtain some information on the particle size and shape (using optical and electron microscope techniques), and we would like to run some x-ray diffraction patterns to obtain a better idea of the chemical form of the plutonium particles. We can be certain that most of the large dust particles that were inhaled were swallowed -- some directly and others after being held up in the upper respiratory tract or brought up by the cilia. The small particles entered into the lower respiratory tract where a large fraction of those less than 0.3μ in diameter were held up in the alveoli from whence some will be dissolved and enter the bloodstream to be deposited in the bone and other body organs and other particles will be phagocytized and concentrated in the lymph nodes. The effective half-life for Pu^{239} is assumed to be 7.2×10^4 days in the bone, 3×10^4 days in the liver, 3.4×10^4 days in the kidney, and recent evidence (from the autopsy data of Mr. Kelley who was involved in the latest criticality accident in Los Alamos*) points to the fact that the effective half-life in the pulmonary lymph nodes is probably at least an order of magnitude greater than the above values, i.e., 10^5 to 10^6 days. If most of the Pu we now find in the urine of our employees is excreted from the lymph nodes, large amounts may be deposited therein. On the other hand, if most of the Pu excreted in the urine is that which was held up temporarily in the blood and in the extracellular fluids, it may be that only very minor quantities of plutonium were taken up in the bodies of ORNL employees. There is considerable evidence that it requires 15 to 20 years for the average pulmonary carcinoma to manifest itself; thus until we obtain autopsy data and/or until many years have elapsed, we may not have all the necessary information to evaluate the human hazards associated with this accident.

In view of the above I have requested that we do the following:

1. Continue for many weeks to run urine analyses on a large number of ORNL employees.

2. Continue to run fecal analyses on those persons engaged in the clean-up operations.

3. Investigate the use of the total body counter in evaluating the total uptake of plutonium and to estimate its distribution in the body. Fortunately this plutonium from cell 6 contained isotopes other than Pu^{239} some of which have gamma spectra more favorable for gamma spectral analysis (e.g., Pu^{241} has a reasonable yield of 0.1 and 0.145 Mev gammas).

4. Refer to Medical all persons who receive any wounds or abrasions of the skin during this clean-up operation. It is rather common practice at other laboratories to excise tissue from wounds contaminated with plutonium.

5. Continue our urine and fecal analyses as well as total body counts on ORNL employees to determine the hazard from the ruthenium fallout accident that occurred prior to this latest accident.

---

*Mr. Kelley did not receive plutonium exposure as a result of the accident, but he had been exposed to plutonium in his work for several years prior to the fatal accident. The autopsy revealed the surprising information that the concentration of plutonium in the lungs was 20 times that in bone (previously considered to be the critical body organ) and the concentration in the pulmonary lymph nodes was 80 times that in bone. During the past few years there has been an increasing amount of exposure to Pu^{240} and Pu^{241} in the Los Alamos laboratories, and this was reflected in the Pu found in the lungs but to a lesser extent in the Pu found in the lymph nodes. This would further indicate an extremely long half-life for Pu in the lymph nodes.

6. Check carefully the hands, face, hair, and clothing of all persons leaving the "hot" areas in Buildings 3019 and 3001.

7. Check the homes of any ORNL employees when there is reason to believe α contamination was tracked into the homes.

K. Z. Morgan

KZM:kd

cc: W. H. Jordan
J. A. Swartout
M. E. Ramsey
C. E. Winters